13

Applications of Dietary Reference Intakes for Macronutrients

This chapter presents a general discussion of the appropriate uses of the Dietary Reference Intakes (DRIs) in the assessment and planning of diets for individuals and for groups. It also provides guidance for the use of the DRIs developed for the nutrients presented in this report, including specific examples and special considerations.

OVERVIEW

The Dietary Reference Intakes (DRIs) may be used for many purposes, most of which fall into two broad categories: assessing current nutrient intakes and planning for future nutrient intakes. Each category may be further subdivided into uses for individual diets and for group diets (Figure 13-1).

For example, the Recommended Dietary Allowance (RDA), Estimated Average Requirement (EAR), and Tolerable Upper Intake Level (UL) may be used in assessing the diet of an individual as one aspect of a nutritional status assessment. The RDA and Adequate Intake (AI) may be used as a basis for planning a diet for the same individual. Likewise, the EAR and UL are used to assess the nutrient intakes of a group, such as persons participating in dietary surveys conducted as part of the National Nutrition Monitoring System. The EAR and UL can also be used to plan nutritionally adequate diets for groups, such as people receiving meals in nursing homes, schools, prisons, and other group settings.

In the past, RDAs in the United States and Recommended Nutrient Intakes (RNIs) in Canada were the primary reference standards available

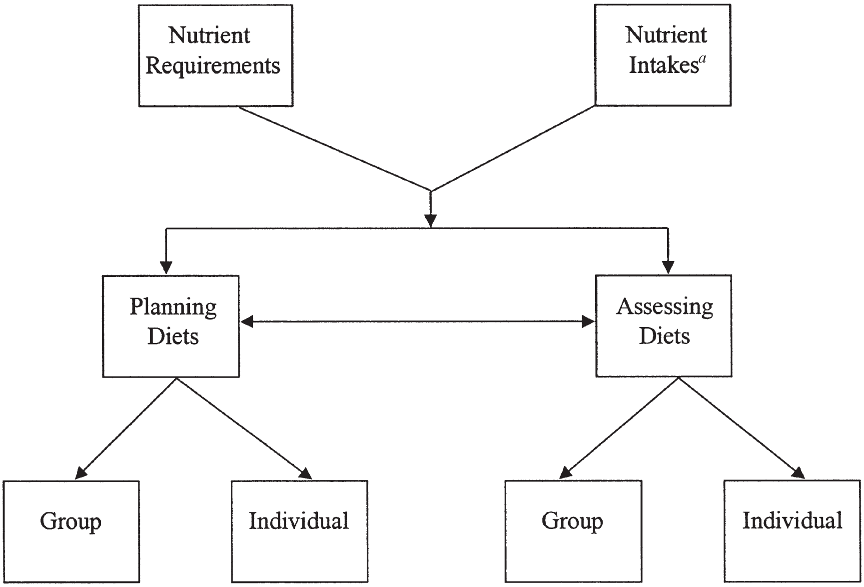

FIGURE 13-1 Conceptual framework—uses of Dietary Reference Intakes.
[a] Food plus supplements.

to health professionals for assessing and planning diets of individuals and groups and for making judgments about inadequate and excessive intake. However, neither the former RDAs nor the RNIs were ideally suited for many of these purposes (IOM, 1994). The DRIs provide a more complete set of reference values. The transition from using the former RDAs and RNIs to using all of the DRIs appropriately will require time and effort by health professionals and others.

Appropriate uses of each of the new DRIs are described briefly in this chapter and in more detail in a report on the application of the DRIs in assessment (IOM, 2000) and in a forthcoming report on their uses in planning. Included in this chapter are specific applications to the nutrients discussed in this report. Details on how the DRIs are set with reference to specific life stage and gender groups, and the primary criterion that defines adequacy for each of these nutrients are given in Chapters 5 through 10.

ASSESSING NUTRIENT INTAKES OF INDIVIDUALS

Dietary assessment methods have several inherent inaccuracies. One is that individuals underreport their intakes (Mertz et al., 1991; Schoeller, 1995; Schoeller et al., 1990), and it appears that obese individuals often do so to a greater extent than do normal-weight individuals (Heitmann and Lissner, 1995). There is no method to adjust intakes to account for under-reporting by individuals and much work is needed to develop an acceptable method. Another inherent inaccuracy is the quality of food composition databases.

Furthermore, large day-to-day variations in intake, which are exhibited by almost all individuals, mean that it often takes a prohibitively large number of days of intake measurement to approximate usual intake (Basiotis et al., 1987). As a result, caution is indicated when interpreting nutrient assessments based on self-reported dietary data covering only a few days of intake. Data on nutrient intakes should be interpreted in combination with information on typical food usage patterns to determine if the recorded intakes are representative of that individual's usual intake.

Finally, because there is considerable variation in intakes both within and between individuals, as well as variation associated with the requirement estimate, other factors must be evaluated in conjunction with the diet. The Dietary Reference Intakes (DRIs) should be used in conjunction with other data in assessing the adequacy of the diet of a specific individual. The nutritional status of an individual can be definitively determined only by a combination of dietary, anthropometric, physiological and biochemical data.

Using the Estimated Average Requirement and the Recommended Dietary Allowance

The Estimated Average Requirement (EAR) estimates the median of a distribution of requirements for a specific life stage and gender group, but it is not possible to know where an individual's requirement falls within this distribution without further anthropometric, physiological, or biochemical measures. Thus from dietary data alone, it is only possible to estimate the *likelihood* of nutrient adequacy or inadequacy. Furthermore, only rarely are precise and representative data on the usual intake of an individual available, adding additional uncertainty to the evaluation of an individual's dietary adequacy.

An approach for using data from dietary records or recalls to estimate the likelihood that an individual's nutrient intake is adequate is presented in *Dietary Reference Intakes: Applications in Dietary Assessment* (IOM, 2000). This approach is appropriate for nutrients with symmetrical requirement distributions, which is thought to be true for all macronutrients in this report for which EARs have been established. The following data are required:

- individual's mean nutrient intake over a given number of days
- day-to-day standard deviation (SD) of intakes for each nutrient of interest, as estimated from larger data sets for the appropriate life stage and gender group
- EAR
- SD of the nutrient requirement in the individual's life stage and gender group.

From this information a ratio is computed that compares the magnitude of difference between the individual's intake and the EAR to an estimate of variability of intake and requirements. The bigger the difference between intake and EAR and the lower the variability of intakes and requirements, the greater is the degree of certainty in assessing whether the individual's nutrient intake is adequate, inadequate, or excessive. This approach is quantitative and should be used only when the data listed above are available.

However, in the more common situation where the estimate of usual intake is not based on actual 24-hour recalls or records, but on dietary history or food frequency questionnaires, a qualitative interpretation of intakes can be used. For example, many practitioners use the diet history method to construct a likely usual day's intake, but the error structure associated with this method is unknown. While the error associated with food frequency questionnaires has been evaluated (Carroll et al., 1996; Liu, 1994), use of these tools for quantitative nutrient assessment is still not possible due to lack of accurate portion size estimates and grouping of food items (IOM, 2000). Thus, a practitioner should be cautious when using this method to approximate usual intakes.

Users of the DRIs may find it useful to consider that observed intakes below the EAR probably need to be improved (because the probability of adequacy is 50 percent or less) and those between the EAR and the Recommended Dietary Allowance (RDA) probably need to be improved (because the probability of adequacy is less than 97 to 98 percent). Only if intakes have been observed for a large number of days and are at the RDA, or observed intakes for fewer days are well above the RDA, should one have a high level of confidence that the intake is adequate. Such considerations are not applicable in the case of energy intake, which should match energy expenditure in individuals maintaining desirable body weight (see later section, "Planning Nutrient Intakes of Individuals," and Chapter 5).

Using the Adequate Intake

Adequate Intakes (AIs) have been set for infants younger than 7 months of age for *n*-3 and *n*-6 polyunsaturated fatty acids and protein. By definition, infants born at term who are exclusively fed human milk by healthy mothers consume an adequate nutrient intake. Infants who consume formulas with a nutrient profile similar to human milk (after adjustment for differences in bioavailability) are also assumed to consume adequate levels of nutrients. When an infant formula contains nutrient levels that are lower than those found in human milk, the likelihood of nutrient adequacy for infants who consume this formula cannot be determined because data on infants fed lower concentrations of nutrients are not available. AIs have also been established for infants 7 to 12 months of age for all nutrients covered in this report except protein, and for all individuals for *Total Fiber* and the *n*-3 and *n*-6 polyunsaturated fatty acids.

Equations that can be used to estimate the degree of confidence that an individual's usual intake meets or exceeds the AI are presented (IOM, 2000). The data required include the individual's reported intake over a given number of days, the AI for the age/gender group, and the day-to-day (within-person) SD for the nutrient of interest, as estimated from larger data sets for the appropriate life stage and gender group. Usual individual intakes that are equal to or above the AI can be assumed to be adequate. However, the likelihood of inadequacy of usual intakes below the AI cannot be determined.

Using the Tolerable Upper Intake Level

The Tolerable Upper Intake Level (UL) is used to examine the possibility of over-consumption of a nutrient. Equations have been developed to determine the degree of confidence that an individual's intake is below the UL (IOM, 2000). If an individual's usual nutrient intake remains below the UL, there is no risk of adverse effects from excessive intake. At intakes above the UL, the potential for risk of adverse effects increases. However, the intake at which a given individual will develop adverse effects as a result of taking large amounts of one or more nutrients is not known with certainty. No ULs were set for the macronutrients in this report. However, there is no established benefit to almost all healthy individuals who consume amounts of nutrients that exceed the RDA or AI.

Equations that can be used to estimate the degree of confidence that an individual's usual intake equals or exceeds the UL are presented in *Dietary Reference Intakes: Applications in Dietary Assessment* (IOM, 2000). The data required include the individual's reported intake over a given number of days, the UL for the life stage and gender group, and the day-to-day (within-person) SD for the nutrient of interest, as estimated from larger data sets for the appropriate life stage and gender group.

Using the Acceptable Macronutrient Distribution Range

In addition to presenting DRIs for macronutrients, this report also presents Acceptable Macronutrient Distribution Ranges (AMDRs) for individuals as a proportion of total energy intake. The AMDRs represent intakes that minimize the potential for chronic disease over the long-term, permit essential nutrients to be consumed at adequate levels, and should be associated with adequate energy intake and physical activity to maintain energy balance. The AMDRs for adults are 20 to 35 percent of energy from fat (including 0.6 to 1.2 percent of energy from *n*-3 polyunsaturated fatty acids and 5 to 10 percent of energy from *n*-6 polyunsaturated fatty acids), 45 to 65 percent of energy from carbohydrate, and 10 to 35 percent of energy from protein. For children, the AMDRs for total fat are 30 to 40 percent between the ages of 1 and 3 years, and 25 to 35 percent between the ages of 4 and 18 years. AMDRs for protein and carbohydrate do not vary with age.

To estimate the degree of confidence that an individual's diet falls within the AMDR, the equations developed could be used to estimate the degree of confidence that the individual's intake exceeds the AI or remains below the UL (IOM, 2000). The equation for the AI could be used to determine the degree of confidence that intake is above the lower end of the AMDR, and the equation for the UL could be used to determine the degree of confidence that intake is below the upper end of the AMDR. The data required include the individual's average intake of the macronutrient of interest as a percent of energy intake over a given number of days, the boundaries of the AMDR, and the day-to-day (within-person) SD of percent energy intake, as estimated from larger data sets for the appropriate life stage and gender group.

ASSESSING NUTRIENT INTAKES OF GROUPS

The assessment of nutrient adequacy for groups of people requires unbiased, quantitative information on the intake of the nutrient of interest by individuals in the group. Care must be taken to ensure the quality of the information upon which assessments are made so that they are not underestimates or overestimates of total nutrient intake. Estimates of total nutrient intake, including amounts from supplements, should be obtained. It is also important to use appropriate food composition tables with accurate nutrient values for the foods as consumed.

Several steps must be taken to assess the intake of a group. First, the intake distribution must be adjusted to remove the effect of day-to-day variation of individual intake. This can be accomplished either by collect-

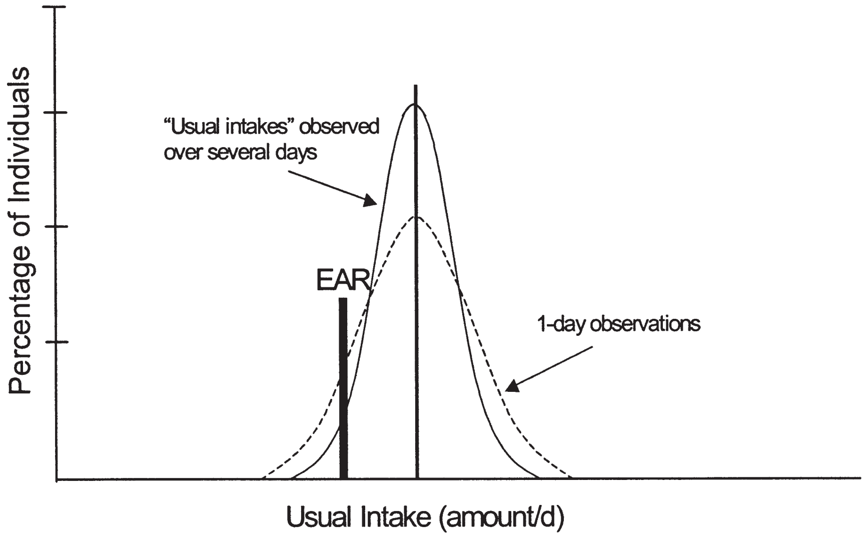

FIGURE 13-2 Comparison of 1-day and usual intakes for estimating the proportion of a group consuming below the Estimated Average Requirement (EAR).

ing dietary data for each individual over a large number of days or by statistical adjustments to the intake distribution. The statistical adjustments are based on assumptions about the day-to-day variation derived from repeat measurements of a representative subset of the group under study (Nusser et al., 1996). When this adjustment is performed and observed intakes are thus more representative of the usual diet, the intake distribution narrows, giving a more precise estimate of the proportion of the group with usual intakes below requirements (Figure 13-2). An explanation of this adjustment procedure has been presented in two previous reports (IOM, 2000; NRC, 1986).

A statistical approach is then used to combine the information on nutrient intakes with the information on nutrient requirements in order to determine the apparent percent prevalence of nutrient inadequacy in the group. Two approaches are briefly described below and in detail elsewhere (IOM, 2000; NRC, 1986).

The Probability Approach

Using the probability approach requires knowledge of both the distribution of requirements and the distribution of usual intakes for the population of interest. As described previously (IOM, 2000; NRC, 1986), the probability approach involves: (1) determining the risk of inadequacy for each individual in the population and then (2) averaging the individual probabilities of inadequacy across the group. Appendix C of *Dietary Reference Intakes: Applications in Dietary Assessment* (IOM, 2000) demonstrates how to carry out the necessary calculations to obtain a prevalence estimate for a group. Statistical programs (e.g., SAS or similar software) can be used to carry out these procedures.

The EAR Cut-Point Method

In most situations a cut-point method using the Estimated Average Requirement (EAR) may be used to estimate the prevalence of inadequate intakes. This cut-point method is a simplification of the full probability approach of calculating the prevalence of inadequacy described by the National Research Council (NRC, 1986). The cut-point method allows the prevalence of inadequate intakes in a population to be approximated by determining the percentage of individuals in the group whose usual intakes are less than the EAR for the nutrient of interest. This method assumes that the intake and requirement distributions are independent, an assumption that is not valid for the energy requirements addressed in this report because energy intakes are highly correlated to energy expenditure. The cut-point method further assumes that the variability of intakes among individuals within the group under study is at least as large as the variability of their requirements. This assumption is usually warranted in free-living populations. Finally, it assumes that the requirement distribution is symmetrical. This is thought to be true for all of the macronutrients discussed in this report.

Using the Estimated Average Requirement

If the assumptions for the EAR cut-point method are met, the prevalence of inadequate intakes may be estimated by the proportion of the distribution of usual intakes that falls below the EAR. An example of using the EAR cut-point method to assess the dietary carbohydrate adequacy of women aged 31 to 50 years follows. Dietary intake data are available from the 1994–1996 Continuing Survey of Food Intakes by Individuals. Estimated intakes are based on respondents' intakes, which were adjusted to remove within-person variability using the Iowa State University method (Appendix Table E-2). The EAR for women in this age group is 100 g/day. Examination of the distribution of usual carbohydrate intake reveals that intakes at the 1st and 5th percentiles are 87 and 118 g/day, respectively. Thus, fewer than 5 percent of women in this age group appear to have inadequate carbohydrate intakes.

Overestimates of the prevalence of inadequate intakes could result if the data used are based on intakes that are systematically underreported or if foods rich in the nutrient of interest are underreported. Such underreporting is common in national surveys (Briefel et al., 1997). Currently, a method for adjusting intakes to compensate for underreporting by individuals is not available, and much work is needed to develop an acceptable method. Conversely, underestimates of the prevalence of inadequacy could result if foods rich in the nutrient of interest were overreported. A more extensive discussion of potential sources of error in self-reported dietary data can be found in the report *Dietary Reference Intakes: Applications in Dietary Assessment* (IOM, 2000).

Comparison of Assessments Using the Probability Approach and Biochemical Assessment

If requirement estimates are correct, dietary intake data are reliable estimates of true usual intake, and biochemical measures reflect the same functional criterion used to set the requirement of a nutrient for the same population, then the prevalence of apparently inadequate dietary intakes and biochemical deficiencies or indicators of inadequacy should be similar.

Using the Recommended Dietary Allowance

The Recommended Dietary Allowances are not useful in estimating the prevalence of inadequate intakes for groups. As described above, the EAR should be used for this purpose.

Using the Adequate Intake

In this report Adequate Intakes (AIs) are assigned for all nutrients for infants through the age of 6 months and reflect the average intake of infants receiving human milk. Human milk and formulas with the same nutrient composition as human milk (after adjustment for bioavailability) provide the appropriate levels of nutrients for full-term infants of healthy, well-nourished mothers. For infants ages 7 to 12 months, AIs are set for carbohydrate and *n*-3 and *n*-6 polyunsaturated fatty acids and reflect the average intakes of infants receiving human milk and complementary foods. Groups of infants consuming formulas with lower levels of nutrients than that found in human milk may be at some risk of inadequacy, although the prevalence of inadequacy cannot be quantified.

This report provides AIs for all life stage and gender groups for *Total Fiber* and *n*-3 and *n*-6 polyunsaturated fatty acids. Groups with median intakes equal to or above the AI for *Total Fiber* and *n*-3 and *n*-6 polyunsaturated fatty acids can be assumed to have a low prevalence of inadequacy (provided that intake variability does not exceed that of the healthy group used to establish the AI). However, when the AI is not set as a mean intake of a healthy group (e.g., fiber), confidence in this assessment should be less than it would be if the AI represents the median intake of a healthy group. It is important to note that group median intakes below the AI cannot be assumed to be inadequate.

Using the Tolerable Upper Intake Level

The proportion of the population with usual intakes below the Tolerable Upper Intake Level (UL) is likely to be at no risk of adverse effects due to overconsumption. However, the proportion of the population consuming above the UL may potentially be at some risk.

The mean intake of a population cannot be used to evaluate the prevalence of intakes above the UL. A distribution of usual intakes, including intakes from supplements, is required to assess the proportion of the population that might be at risk of over-consumption. However, if the mean or median intake is equal to or greater than the UL, it suggests that the number of individuals with excessive intake is high and warrants further investigation.

Using the Acceptable Macronutrient Distribution Range

Although primarily directed at individuals, the Acceptable Macronutrient Distribution Range (AMDR) also permits assessment of populations. By determining the proportion of the group that falls below, within, and above the AMDR, it is possible to assess population adherence to recommendations and to determine the proportion of the population that is outside the range. If significant proportions of the population fall outside the range, concern could be heightened for possible adverse consequences. Planning and public health messages can then be instituted to attempt to attain a low prevalence of intakes below or above the AMDR.

For example, the AMDR for total fat intake of children 4 to 18 years of age is 25 to 35 percent of energy. Appendix Table E-6 presents data on the usual daily intake of total fat as a percentage of energy intake and indicates that for all groups of children and adolescents, the 5th percentile of intake is at least 25 percent. Thus, fewer than 5 percent of children have intakes below the AMDR for total fat. The 75th percentiles of intake are close to 35 percent, suggesting that approximately 25 percent of children and adolescents have intakes above the AMDR for total fat. Intakes of the remaining 70 to 75 percent fall within the AMDR.

PLANNING NUTRIENT INTAKES OF INDIVIDUALS

Using the Recommended Dietary Allowance

Individuals should use the Recommended Dietary Allowance (RDA) as the target for their intakes for those nutrients for which RDAs have been established. Intakes at this level ensure that the risk to individuals of not meeting their requirements is very low (2 to 3 percent). For example, the RDA for protein for adults is 0.8 g/kg/day, or 56 and 46 g/day for reference men and women weighing 70 kg and 57 kg, respectively. For a small adult weighing 45 kg, the recommended protein intake would be 36 g/day, while for a larger adult weighing 90 kg, the RDA would be 72 g/day.

Using the Adequate Intake

Adequate Intakes (AIs) are set for infants younger than 7 months of age for all nutrients, and for all nutrients except protein and indispensable amino acids for infants 7 through 12 months of age. Human milk, by definition, supplies the AI for a nutrient for term infants; it is not necessary to plan additional sources of intake for infants exclusively fed human milk. Likewise, an infant formula with a nutrient profile similar to human milk (after adjustment for differences in bioavailability) should supply adequate nutrients for an infant.

In this report AIs are also set for children, adolescents, and adults for *Total Fiber* and *n*-3 and *n*-6 polyunsaturated fatty acids. Accordingly, individuals should use the AI as their goal for intake of these nutrients.

Using the Tolerable Upper Intake Level

Tolerable Upper Intake Levels (Uls) were not set for the macronutrients covered in this report.

Using the Acceptable Macronutrient Distribution Range

In addition to meeting the RDA or AI and remaining below the UL, an individual's intake of macronutrients should be planned so that carbohydrate, total fat, *n*-3 and *n*-6 polyunsaturated fatty acids, and protein are within their respective Acceptable Macronutrient Distribution Ranges.

PLANNING NUTRIENT INTAKES OF GROUPS

Using the Estimated Average Requirement and the Tolerable Upper Intake Level

For those nutrients with Estimated Average Requirements (EAR), the EAR may be used as a basis for planning or making recommendations for the nutrient intakes of groups. The mean intake of a group should be high enough so that only a small percentage of the group would have intakes below the EAR, thus indicating a low prevalence of dietary inadequacy. The approach to planning for a low prevalence of inadequacy differs depending on whether or not the distributions of intake and requirements are normally distributed. Additional details are provided in the forthcoming Institute of Medicine report on dietary planning.

For example, assume that the goal of planning was to target a 2 to 3 percent prevalence of inadequacy for a nutrient for which both requirement and intake distributions were statistically normal. This would be attained by planning a group mean intake equal to the EAR plus 2 standard deviations (SD) of the *intake* distribution. Because the variability of intakes generally exceeds the variability of requirements, this target group mean intake will usually exceed the Recommended Dietary Allowance (which equals the EAR plus 2 SDs of the *requirement* distribution). Prevalence of inadequacy more or less than 2 to 3 percent could also be considered. Mean intakes needed to attain the desired prevalence would be estimated by determining the number of SDs of intake added to the EAR that would result in the desired percentage prevalence below the EAR. This can be done by consulting tables that list areas under the curve of the standard normal distribution in relation to SD scores (z-scores).

When the distribution of intakes is skewed (as is true for intakes of most nutrients), a low prevalence of inadequacy can be attained by planning to position the intake distribution such that only the targeted proportion is below the EAR. Finally, when it is known that requirements for a nutrient are not normally distributed and one wants to ensure a low group prevalence of inadequacy, it is necessary to examine both the intake and requirement distributions to determine a median intake at which the proportion of individuals with intakes below requirements is likely to be low.

In addition to planning for an acceptably low group prevalence of intakes below the EAR, the planned distribution also needs to be examined to ensure that the prevalence of intakes above the Tolerable Upper Intake Level (UL) is also acceptably low.

Using the EAR and UL in planning intakes of groups involves the analysis of data and a number of key considerations such as:

- determination of the current usual nutrient intake distribution of the group of interest expressed in the same unit as the EAR (e.g., g/day, g/kg/day, percent of energy);
- selection of the degree of risk that can be tolerated when planning for the group (e.g., a 2 to 3 percent prevalence versus a higher or lower prevalence); and
- consideration of various possible interventions to shift the current distribution, if necessary, to produce an acceptably low prevalence of intakes below the EAR, as well as an acceptably low prevalence of intakes above the UL; some targeted interventions may increase the intake of only those most at risk, while other interventions (e.g., fortification of the food supply) may increase the intake, to varying degrees, of the majority of the population.

Using the Adequate Intake in Planning for Groups

As indicated previously, Adequate Intakes (AIs) have been established for some of the nutrients discussed in this report. Planning a median group intake that meets the AI should, by definition, be associated with a low prevalence of inadequacy, if the AI was set as the median intake of a healthy group and the group being planned for has similar characteristics to the group used to establish the AI. If the AI was not set as the median intake of a healthy group (e.g., the AI for *Total Fiber*), there is less confidence that the prevalence of inadequacy would be low if the group's median intake met the AI.

Using the Acceptable Macronutrient Distribution Range

In addition to ensuring that the group prevalence of intakes below the EAR or above the UL is acceptably low, an additional goal of planning is to achieve a macronutrient distribution in which the intakes of most of the group fall within the Acceptable Macronutrient Distribution Ranges (AMDRs). There may be a tendency for planners to develop menus and patterns in which the mean population intakes are at the midpoint of the AMDRs; this is one method to plan for low prevalence of intakes below or above the AMDR. For example, a meal program for a university dormitory might be planned using the midpoint of the ranges for carbohydrate and fat (for adults, these would be 55 and 28 percent of energy, respectively). The remaining 17 percent of energy would come from protein. Assessment would be needed to determine whether intakes of most members of the group fell within the AMDR, or whether interventions were required to target one end of the distribution (e.g., those with fat intakes above 35 percent). However, planning for the midpoint of a range is not the only way that the AMDR can be used to plan for groups. Using the university dormitory example, a dietary pattern might be planned in which the mean intake from fat was 30 percent of energy. Assessment conducted following implementation of the program might reveal that actual fat intakes of the students ranged from about 25 percent to about 35 percent of energy. In other words, the prevalence of intakes outside the acceptable range is low, despite a mean fat intake that is higher than the midpoint of the range. While the AMDR can be used as a general quantitative guideline for planning and evaluating diets, qualitative considerations, such as a menu low in saturated fats, may be at least as important as these quantitative guidelines (see Chapter 11).

NUTRIENT-SPECIFIC CONSIDERATIONS

Energy

Planning Energy Intakes for Individuals

The underlying objective of planning for energy is similar to planning for nutrients—to attain an acceptably low risk of inadequacy and of excess. The approach to planning for energy, however, differs substantially from planning for other nutrients. When planning for an individual's intake of nutrient such as vitamins and minerals, the goal is a low risk of inadequacy by meeting the Recommended Dietary Allowance (RDA) or Adequate Intake (AI), and a low risk of excess by remaining below the Tolerable Upper Intake Level (UL). Even though intakes at or above the RDA or AI are almost certainly above an individual's requirement, there are no adverse effects to the individual of consuming an intake above his or her requirement, provided intake remains below the UL; however there are also no documented benefits.

The situation for energy is quite different. There are adverse effects to individuals who consume energy above their requirements—over time, weight gain will occur. This difference is reflected in the fact that there is no RDA for energy, as it would be inappropriate to recommend an intake that exceeded the requirement (and would lead to weight gain) of 97 to 98 percent of individuals. The requirement for energy for individuals of normal weight is expressed as an Estimated Energy Requirement (EER), which reflects the energy expenditure associated with an individual's sex, age, height, weight, and physical activity level.

Equations are presented to estimate an individual's energy expenditure, with separate equations for normal (body mass index [BMI] > 18.5 and < 25) and overweight (BMI ≥ 25) individuals, as well as for all individuals with BMI > 18.5 (i.e., including normal, overweight, and obese subjects).

For overweight individuals, these equations estimate Total Energy Expenditure (TEE), rather than the EER, which is reserved for normal weight individuals. In all cases, however, the equations estimate the energy expenditure associated with maintaining current body weight and activity level. They were not developed, for example, to lead to weight loss in overweight individuals. However, just as is the case with other nutrients, energy expenditures vary from one individual to another, even though their characteristics may be similar. This variability is reflected in the standard deviation (SD), which allows for estimation of the range within which the individual's energy expenditure could vary. Note that this does not imply that an individual would maintain energy balance at any intake within this range; it simply indicates how variable requirements could be among those with similar characteristics.

For example, the equation for the EER of women ages 19 years and older with a BMI > 18.5 and < 25 is:

$$\text{Energy (kcal)} = 354.1 - (6.91 \times \text{age [y]}) + \text{physical activity coefficient} \\ \times (9.36 \times \text{weight [kg]} + 726 \times \text{height [m]})$$

The SD is 160 kcal. Therefore, the EER for a normal-weight, 33-year-old low-active woman (i.e., with a physical activity level (PAL) between 1.4 and 1.59, for whom the physical activity coefficient is 1.12), with a height of 1.63 m and a weight of 55 kg would be:

$$\text{Energy (kcal)} = 354.1 - (6.91 \times 33) + 1.12 \\ \times (9.36 \times 55 + 726 \times 1.63) = 2{,}028$$

The 95 percent confidence interval for this equation reflects the range within which a given individual's energy expenditure likely falls, and in this example, it would be 2,028 ± (2 × 160), or between 1,708 and 2,348 kcal/day. It must be realized that considerable uncertainties are inherent in making such predictions, notably because of possible misclassification of individuals into the various PAL categories (i.e., sedentary, low active, active, and very active).

Usual energy intakes are highly correlated with expenditure when considered over periods of weeks or months. This means that most people who have access to enough food will, on average, consume amounts of energy very close to the amounts that they expend, and as a result, maintain their weight over extended periods of time. Any changes in weight that do occur usually reflect small imbalances accumulated over a long period of time. For normal individuals who are weight-stable, at a healthy weight, and performing at least the minimal recommended amount of activity, their energy requirement (and recommended intake) is their usual energy intake. Thus, if an individual's usual energy intake were known, the plan would be to maintain it rather than use the EER (or if overweight, the TEE). In many situations, however, the usual energy intake of an individual is not known, and the estimated energy requirement equations are useful planning tools.

Using the EER (or TEE) to Maintain Body Weight. When the goal is to maintain body weight in an individual with specified characteristics (age, height, weight, and activity level), an initial estimate for energy intake is provided by the equation for the energy expenditure of an individual with those characteristics. By definition, the estimate would be expected to underestimate the true energy expenditure 50 percent of the time and to overestimate it 50 percent of the time, leading to corresponding changes in body weight. This indicates that monitoring of body weight would be required when implementing intakes based on the equations that predict individual energy requirements. For example, if subjects were enrolled in a study in which it was important to maintain body weight, each individual would be fed the amount of energy estimated to be needed based on the EER equation. Body weight would be closely monitored over time, and the amount of energy provided to each individual would be adjusted up or down from the EER (or TEE) as required to maintain body weight.

Using the EER (or TEE) to Plan to Prevent Weight Loss. In some situations the goal of planning might be to prevent weight loss in an individual with specified characteristics. In this situation, the EER or TEE equation could be used to derive the average energy expenditure for the individual, and then an amount equal to two times the SD added. This would lead to an intake that would be expected to exceed the actual energy expenditure of all but 2 to 3 percent of the individuals with similar characteristics. Using the above example for the 33-year-old, low-active woman, one would provide 2,028 + (2 × 160) kcal, or 2,348 kcal. This intake would prevent weight loss in almost all individuals with similar characteristics. Of course, this level of intake would lead to weight gain in most of these individuals.

Using the EER (or TEE) to Plan to Prevent Weight Gain. If the goal of planning is to prevent weight gain in an individual with specified characteristics, the appropriate EER equation could be used to derive the average energy expenditure for the individual, and then subtract an amount equal to two times the SD. This would lead to an intake that would be expected to fall below the actual energy requirements of all but 2.5 percent of the individuals with similar characteristics. Using the above example for the 33-year-old, low-active woman, the energy requirement would be 2,028 – (2 × 160) kcal, or 1,708 kcal. This intake would prevent weight gain in almost all individuals with similar characteristics. Of course, this level of intake would lead to weight loss in most of these individuals.

Planning for Energy for Groups

As is true for individuals, the underlying objective in planning the energy intake of a group is similar to planning intakes for other nutrients—to attain an acceptably low prevalence of inadequacy and of potential excess. The approach to planning for energy, however, differs substantially from planning for other nutrients. When the Estimated Average Requirement (EAR) cut-point method is used to plan for a group's intake of nutrients such as vitamins and minerals, a low prevalence of inadequacy is obtained by positioning the intake distribution such that an acceptably low proportion of the group has an intake below the EAR. A low prevalence of potential risk of excess is obtained by positioning the intake distribution such that an acceptably low proportion of the group has an intake above the UL. Even though the planned distribution of intakes would exceed the actual requirements of all but the designated proportion of the group (in many cases, by a considerable margin), there are no known adverse effects to the group of consuming vitamins and minerals in amounts that exceed requirements, provided the proportion above the UL also remains low.

In the case of energy, however, there *are* adverse effects for the individuals in the group whose intakes are above their requirements, as weight gain is bound to occur over time. Therefore, the EAR cut-point method to plan for group intakes of energy is clearly inappropriate. In addition, the assumptions required to apply this method, as well as for the probability approach, do not hold for energy. Most notably, the methods assume that intakes are essentially uncorrelated with requirements. In the case of energy, however, intakes are very highly correlated with requirements.

What, then, can be done to plan for energy intakes of groups? There are two possible approaches: estimate energy requirements for the reference person or obtain an average of estimated maintenance energy needs for group members.

Estimate Energy Requirements for the Reference Person. One approach is to use the EER for the reference person who represents the group. For example, to plan for a large group of men ages 19 to 30 years, estimate the EER for the reference male with a weight of 70 kg and a height of 1.76 m and who is considered low active, and use this number (~2,700 kcal) as the target for the group. This approach would require the assumption that all members of the group were similar to the reference person, or that the reference individual accurately represented group average values for age, height, weight, and activity level, and that these variables were symmetrically distributed. If either assumption held, the resulting EER would approximate the group mean energy requirement.

However, if the assumptions did not hold true, as is likely in many situations, the estimates would be incorrect. At a practical level, it is likely that the estimate obtained would be less than the true average energy expenditure of the group, since for most life stage and gender groups the reference person weighs less than the average person.

Obtain an Average of Estimated Maintenance Energy Needs for Group Members. The preferred approach would be to plan for an intake equal to the average energy expenditure for the group. For example, using the same group of 19- to 30-year-old men from the previous section, the energy expenditure for each individual in the group would be estimated (assuming access to data on height, weight, age, and activity level). The average of these values would be used as the planning goal for maintenance of current weight and activity level. Table 13-1 shows an example of how this is done for a small group of six healthy men with a BMI < 25. If the group included men with a BMI > 25, the equations developed to estimate the Total Energy Expenditure for overweight individuals would be used for those individuals with BMI > 25.

In this hypothetical example, the average planned intake exceeds the EER of five of the men, and is below the EER of one large, very active man (in a larger, more homogeneous group, the estimate would be expected to

TABLE 13-1 Obtaining an Average Estimated Energy Requirement (EER) for a Group

Subject	Age (y)	Height (m)	Weight (kg)	Physical Activity Level	Physical Activity Level Coefficient	EER[a] (kcal)
1	21	1.83	95	Sedentary	1.0	2,961
2	27	1.77	75	Low active	1.12	2,811
3	25	1.69	60	Active	1.27	2,794
4	19	1.80	75	Low active	1.12	2,905
5	30	1.73	80	Very active	1.45	3,575
6	25	1.75	75	Low active	1.12	2,818
Mean	24.5	1.76	76.7	—	1.18	2,977

[a] Energy (kcal) = 661.8 – 9.53 × age (y) + physical activity coefficient × [15.91 × weight (kg) + 539.6 × height (m)]. Physical activity level coefficient = 1.0 (sedentary), 1.12 (active), 1.45 (very active).

be inadequate for half the men and above the requirement for the other half). However, because intakes and expenditures are highly correlated, and assuming that all members of the group have free access to food, most members of the group will consume an amount of energy equal to their expenditure. Thus, planning for an intake that approximates the mean energy expenditure should allow the group to meet energy needs for weight maintenance and current activity levels.

Caveats. As with other planning applications, it should be emphasized that the planning goal is for energy intakes. The above approach requires the assumption that free access to food is available, that each member of the group consumes an amount of energy that approximates their individual expenditure, and that food is not wasted or spoiled. As with other planning examples, food waste and to what extent the amount of energy offered would need to exceed the target median intake need to be considered. Assessing the plan following its implementation would lead to further refinements.

Assessing Energy Intakes

As was true for planning, the approach to assessing the adequacy of energy intakes differs from that described for other nutrients. This arises in part from theoretical considerations. Perhaps more importantly though, it is related to the fact that for energy, unlike most nutrients, a readily observable, accurate biological indicator—body weight—can be used to assess the long-term adequacy of energy intake. An individual or group with a BMI above the desirable range reflects long-term excess energy intake, while the converse is true when BMI is below the desirable range.

The availability of a biological indicator to assess the adequacy of energy intake becomes particularly critical because of the effect of dietary underreporting on the assessment of adequacy. It is now widely accepted, and supported by a large body of literature, that underreporting of food intake is pervasive in dietary surveys (Black et al., 1993). Underreporters can constitute anywhere from 10 to 45 percent of the total sample, depending on the age, gender, and body composition of the sample. Underreporting tends to increase in prevalence as children age (Livingstone et al., 1992), and is greater among women than among men (Johnson et al., 1994). Both the prevalence and severity of underreporting is greater among obese individuals compared with lean individuals (Bandini et al., 1999; Lichtman et al., 1992; Prentice et al., 1986). In addition, those of low socioeconomic status (characterized by low incomes, low educational attainment, and low literacy levels) are more likely to report low energy intakes (Johnson et al., 1998; Kristal et al., 1997; Pryer et al., 1997). Therefore, self-reported energy intakes do not reflect actual energy intakes, and other methods must be used to determine their adequacy. Relative body weight (as reflected by BMI) is a preferred indicator of energy adequacy for individuals and for groups.

Assessing Adequacy of Energy Intakes of Individuals. Theoretically, one could compare the usual energy intake of an individual to his or her requirement to maintain current weight and activity level, as estimated using the equations developed to estimate energy expenditure. However, as noted above, the EER (or TEE) equation provides an estimate that is the midpoint of the range within which the expenditure of an individual with specified characteristics could vary, and the individual's actual expenditure could be considerably above or below the midpoint. Accordingly, comparing the individual's intake to the calculated average expenditure is essentially meaningless. For example, the EER for a 33-year-old, low-active woman with a height of 1.63 m and a weight of 55 kg would be calculated at 2,028 kcal, but expenditure for a woman with these characteristics could vary between 1,708 and 2,348 kcal. If the woman's actual energy intake averaged 2,200 kcal, her actual intake could be inadequate, adequate, or excessive.

BMI, in contrast, provides a useful indicator of the adequacy of usual energy intake in relation to usual energy expenditure. If the woman in the above example had a BMI of 22 (i.e., within the healthy range of > 18.5 and < 25), her usual energy intake would be assessed as adequate relative to her usual expenditure. If her BMI was 17 (below the healthy range), then she would be assessed as having an inadequate energy intake; if it was 33 (above the healthy range), her intake would be assessed as excessive.

Assessing Adequacy of Energy Intakes of Groups. Instead of assessing the adequacy of energy intake by comparing reported intakes (which are almost always affected by considerable underreporting) to estimated expenditure, relying on BMI as a biological indicator is preferable. The distribution of BMI within a population group can be assessed, and the proportions of the group with BMI below, within, and above the desirable range would reflect the proportions with inadequate, adequate, and excessive energy intakes. When this approach is applied to body-weight data of adults ages 19 to 50 years obtained in the Continuing Survey of Food Intakes by Individuals, 59 percent of men and 44 percent of women are found to have a BMI ≥ 25, reflecting excessive energy intake; 40 percent of men and 52 percent of women have a BMI within the ideal range, reflecting adequacy; and 0.9 percent of men and 4.6 percent of women have a BMI below 18.5, reflecting inadequacy.

Although the above discussion refers to the adequacy of energy intake, it should be reiterated that intake is just one component of energy balance. Excessive intake must be interpreted as being excessive *in relation to energy expenditure*. In many cases, intake may not be excessive in absolute terms; instead, inadequate energy expenditure may be the primary factor in contributing to long-term positive energy balance. This has important implications for how this issue is best addressed at the population level. There are a number of reasons why increased energy expenditure may be a more appropriate solution than decreased energy intake to long-term positive energy balance (i.e., overweight). First, restricting energy intake also decreases the ability to meet requirements of many nutrients. Second, evidence exists to support the concept that much of the health risk attributed to an increased BMI is associated with poor fitness. Increasing physical activity, thereby improving fitness, improves health outcomes of overweight individuals irrespective of changes in relative weight (Blair et al., 1993, 1995).

Implications of Underreporting for Other Macronutrients. In addition to the major impact of underreporting on assessment of the adequacy of energy intake, it also has potential implications for other macronutrients. If it is assumed that underreporting of macronutrients occurs in proportion to underreporting of energy intake, macronutrients expressed as a percentage of energy would be relatively accurate. Accordingly, there would be little impact on the estimated proportions of those whose intakes fall outside the Acceptable Macronutrient Distribution Ranges (AMDRs) for carbohydrate, protein, total fat, and *n*-3 and *n*-6 polyunsaturated fatty acids. Underreporting would, however, overestimate the prevalence of dietary inadequacy for protein, indispensable amino acids, and carbohydrate. Conversely, it has been suggested that underreporting of nutrients may not occur in proportion to underreporting of energy (IOM, 2000). If, for example, fat intake is preferentially underreported, this would lead to an underestimate of the proportion of those whose intakes are above the upper end of the AMDRs for total fat and for *n*-3 and *n*-6 polyunsaturated fatty acids. It could also lead to an overestimate of the percentage of energy derived from carbohydrate.

Total Carbohydrate

The Dietary Reference Intakes (DRIs) for total carbohydrate (starches and sugars) are set in this report as EARs and RDAs, expressed as absolute amounts (g/day) that support brain glucose utilization. The RDA for carbohydrate (130 g/day) is an average minimum requirement and is lower than what most North Americans consume (Appendix Table E-2). A UL is not established for total carbohydrate. Most people can meet their requirement for carbohydrate without difficulty by consuming a varied diet containing breads, rice, other grain products, potatoes, fruits, vegetables, milk products, and (in moderate amounts) starch- or sugar-based snack foods.

As discussed in Chapter 11, to achieve a healthful balance of the macronutrients that supply energy, the AMDR for total carbohydrate is 45 to 65 percent of energy. This range allows for intakes of carbohydrate that exceeds the RDA of 130 g/day. The carbohydrate content of most U.S. diets is either less than or within this range (see Appendix Table E-3), but it is more likely to be within this range if food selections emphasize grains, fruits, and vegetables prepared with minimal or modest amounts of fat.

Added Sugars

Added sugars are defined as sugars and syrups that are added to foods during processing or preparation. Major sources of added sugars include soft drinks, cakes, cookies, pies, fruitades, fruit punch, dairy desserts, and candy (USDA/HHS, 2000). Specifically, added sugars include white sugar, brown sugar, raw sugar, corn syrup, corn-syrup solids, high-fructose corn syrup, malt syrup, maple syrup, pancake syrup, fructose sweetener, anhydrous dextrose, and crystal dextrose. Since added sugars provide only energy when eaten alone and lower nutrient density when added to foods, it is suggested that added sugars in the diet should not exceed 25 percent of total energy intake. Usual intakes above this level place an individual at potential risk of not meeting micronutrient requirements. Nutrient data on added sugars has only recently become available in the U.S. Department of Agriculture's (USDA) Pyramid Servings Database, which includes data on added sugars for over 7,000 foods. Appendix Table D-1 describes the Third National Health and Nutrition Examination Survey (NHANES III) results on the distribution of intakes of added sugar.

To assess the sugar intakes of groups requires knowledge of the distribution of usual added sugar intake as a percent of energy intake. Once this is determined, the percentage of the population exceeding the maximum suggested level can be evaluated. Because the criterion for the suggested maximum intake level of added sugars is the risk of associated inadequate intakes of micronutrients, such an evaluation would be complemented by assessing micronutrient intakes, as described in the DRI report for those nutrients (IOM, 2001) and the report on dietary assessment (IOM, 2000).

Dietary, Functional, and Total Fiber

Dietary Fiber is defined in this report as nondigestible carbohydrates and lignin that are intrinsic and intact in plants. *Functional Fiber* is defined as isolated, nondigestible carbohydrates that have beneficial physiological effects in humans. *Total Fiber* is the sum of *Dietary Fiber* and *Functional Fiber.* Fiber includes viscous forms that lower serum cholesterol concentrations (i.e., soluble fiber: oat bran, beans) and the bulking agents that improve laxation (i.e., insoluble fiber: wheat bran). The AI for *Total Fiber* is 38 and 25 g/day for 19- to 50-year-old men and women, respectively, based on a reduced risk of coronary heart disease for those within the highest quintiles of dietary fiber consumption (g/1,000 kcal) in several epidemiological studies and the median energy intake (Appendix Table E-1). Unlike the AI for some nutrients, this AI does not describe the median *Total Fiber* intake of a healthy population. Instead, it is based on health benefits associated with consuming foods that are rich in fiber. Based on CSFII data (Appendix Table E-4), the median *Dietary Fiber* intakes are 16.5 to 17.9 g/day for men and 12.1 to 13.3 g/day for women. Thus, it is evident that to meet the AI, most people will need to substantially increase their *Total Fiber* intake. Usual intakes that meet or exceed the AI can be assumed adequate, but the likelihood of inadequacy of usual intakes below the AI cannot be determined.

Fiber consumption can be increased by substituting whole grain or products with added cereal bran for more refined bakery, cereal, pasta, and rice products; by choosing whole fruits instead of fruit juices; by consuming fruits and vegetables without removing edible membranes or peels; and by eating more legumes, nuts, and seeds. For example, whole wheat bread contains three times as much *Dietary Fiber* as white bread, and the fiber content of a potato doubles if the peel is consumed. The soluble and insoluble fiber components of 228 U.S. foods have been published by Marlett and Cheung (1997).

Dietary fiber data are listed for a wide range of foods in the USDA Nutrient Database for Standard Reference (USDA, 2001). The dietary fiber values in the USDA database represent *Total Fiber* (including both dietary and functional fiber) as defined in this report. For most diets (those that have not been fortified with *Functional Fiber* that was isolated and added for health purposes), the contribution of *Functional Fiber* is minor relative to the naturally occurring *Dietary Fiber.* For example, the *Functional Fiber* content for foods such as fat-free yogurts and ice creams that contain added guar gums and carrageenan is so low that the USDA database generally indicates zero dietary fiber for these foods. Although the AI is set for *Total Fiber,* this AI is generally based upon the fibers present in foods, and until these terms are further incorporated into nutrient databases, it is appropriate to apply the *Dietary Fiber* data from the USDA database to the AI for *Total Fiber.*

Because there is insufficient evidence of deleterious effects of high *Dietary Fiber* as part of an overall healthy diet, a Tolerable Upper Intake Level has not been established.

Total Fat and n-*3 and* n-*6 Polyunsaturated Fatty Acids*

Total Fat

No RDAs or AIs are set for total fat, but an AMDR of 20 to 35 percent of energy is recommended for adults (Chapter 11). Thus, when planning diets for individuals, it is necessary to first calculate the individual's estimated energy expenditure, determine 20 and 35 percent of this number in kilocalories, and then divide by 9 kcal/g to get the range of fat intake in grams per day. For example, a person whose energy expenditure was 2,300 kcal/day should aim for an energy intake from fat of 460 to 805 kcal/day. In grams of total fat, intake should be between 51 and 89 g/day.

Likewise, when assessing fat intakes of individuals, the goal is to determine if usual energy intake from total fat is between 20 and 35 percent. As illustrated above, this is a relatively simple calculation assuming both usual fat intake and usual energy intake are known. However, because dietary data are typically based on a small number of days of records or recalls, it may not be possible to state with confidence that a diet is within this range. As explained in the DRI dietary assessment report (IOM, 2000), an adjustment can be made for the likelihood that these are not representative days, based on the day-to-day variation in fat intake and the number of days of dietary data.

When planning fat intakes for groups, the goal is to minimize the intakes of total fat that are outside the AMDR of 20 to 35 percent of energy from fat. If planning is for a confined population, a procedure similar to the one described for individuals may be used: determine the necessary energy intake from the planned meals and plan for a fat intake that provides between 20 and 35 percent of this value. If the group is not confined, then planning intakes is more complex and ideally begins with knowledge of the distribution of usual energy intake from fat. Then the distribution can be examined, and feeding and education programs designed to either increase, or more likely, decrease the percent of energy from fat.

Assessing the fat intake of a group requires knowledge of the distribution of usual fat intake as a percent of energy intake. Once the distribution is described, the percent of the population outside the AMDR can be calculated. For example, Appendix Table E-6 shows that in the CSFII, less than 1 percent of the population was below 20 percent of energy from fat, while over 50 percent consumed greater than 35 percent of energy from fat.

n-*3 and* n-*6 Polyunsaturated Fatty Acids*

n-3 and *n*-6 Polyunsaturated fatty acids have an AI based on median intakes of linoleic acid and α-linolenic acid from CFSII, respectively. In addition to an AI, an AMDR is provided for *n*-3 and *n*-6 fatty acids. The suggested range is 0.6 to 1.2 percent of energy from *n*-3 fatty acids and 5 to 10 percent of energy from *n*-6 fatty acids. Thus, there are several considerations when planning and evaluating *n*-3 and *n*-6 fatty acid intakes. Usual intakes that meet or exceed the AI can be assumed adequate, but the likelihood of inadequacy of usual intakes below the AI cannot be determined. Assessing *n*-3 and *n*-6 fatty acid intakes of groups against the AMDR requires knowledge of the distribution of usual fatty acid intake as a percentage of energy intake. Once the distribution is described, the percentage of the population outside the AMDR can be calculated.

Saturated Fatty Acids, Trans *Fatty Acids, and Cholesterol*

No RDAs, AIs, or AMDRs are provided for saturated fatty acids, *trans* fatty acids, and cholesterol. However, with increasing intakes of either of these three nutrients, there is an increased risk of coronary heart disease. Chapter 11 provides some dietary guidance on ways to reduce the intake of saturated fatty acids, *trans* fatty acids, and cholesterol. For example, when planning diets, it is desirable to replace saturated fat with either monounsaturated or polyunsaturated fats to the greatest extent possible.

Protein and Amino Acids

The EARs and RDAs for protein and amino acids have been expressed as grams per kilogram per day, the first DRIs to be expressed in this way. This implies that requirements and recommended intakes vary among individuals of different sizes, and should be individualized when used for dietary assessment or planning. The potential implications of this are discussed below.

Dietary Assessment

For most nutrients for which EARs have been defined, the prevalence of inadequate intakes can be estimated as the proportion of the distribution of usual intakes that falls below the EAR using the EAR cut-point method (IOM, 2000). However, this method requires a number of assumptions, including that the individual requirement for the nutrient in question has a symmetric distribution. As described in Chapter 10, the distribution of the individual requirement for protein for adults is skewed, however, this skewing appears to be slight and the EAR cut-point method is expected to provide a good approximation to prevalence.

However, if more accuracy is needed, the "probability approach" can be used. This approach has been described elsewhere (IOM, 2000; NRC, 1986), and its application for assessing the prevalence of inadequacy of iron intakes has been illustrated (IOM, 2002). The probability approach for assessing the adequacy of protein intakes is identical to that outlined for iron, with the simplification that percentiles of protein requirement can be explicitly calculated from the formula given in Chapter 10 ("RDA Summary, Ages 19–50 Years").

Planning the Diet

When planning a diet for an individual, recommended intakes can be determined on the basis of the individual's body weight. Although the RDA for the reference adult male is 56 g/day of protein (based on 0.8 g/kg/day for a 70-kg person), the recommended intakes for men weighing 60 kg and 90 kg would be 48 and 72 g/day, respectively.

It should be noted that the DRIs are intended to apply to healthy individuals. Thus, determining a recommended protein intake based on current body weight may not be appropriate for those who are significantly underweight or overweight. For example, a medical professional might choose to specify a protein intake for a malnourished, underweight patient based on what the patient's body weight would be if he were healthy. A patient weighing 40 kg, whose body weight when healthy was 55 kg, could thus have a recommended protein intake of 44 g/day (55 kg × 0.8 g/kg), rather than the 32 g/day that would be determined based on current weight. Conversely, protein intakes recommended for individuals who are morbidly obese could be based on the amounts recommended for those with more normal body weights.

Are Planning and Assessing Intakes of Indispensable Amino Acids Necessary?

The previous RDAs and Recommended Nutrient Intakes did not include recommended intakes for indispensable amino acids; it was assumed that individuals consuming a mixed diet with recommended amounts of protein would obtain required amounts of indispensable amino acids. In other words, it was not necessary to assess or plan for intakes of indispensable amino acids. Now that EARs and RDAs have been provided for indispensable amino acids, it is important to re-examine the question: Is it necessary to consider indispensable amino acids when conducting dietary planning and assessment, or is it sufficient to consider only total protein?

The simplest scenario for answering this question relates to dietary planning for individuals. When planning for individuals, the objective is to meet the RDA, as doing so ensures a very low risk of inadequacy. Thus, do diets that provide the RDA for protein also provide the RDAs for indispensable amino acids? It appears that this may not necessarily occur, at least for the amino acid lysine. Data in Table 13-2 suggest that although most protein sources provide recommended amounts of threonine, tryptophan, and sulfur-containing amino acids, this is not true for lysine. Animal protein sources provide recommended intakes of lysine, but it is clear that individuals who do not consume animal protein sources, or who consume limited amounts, would be unlikely to obtain the recommended amounts of lysine when total protein intake is equal to the RDA, unless their diets were usually high in beans or other legumes. Even then, diets could be marginal, as the data in Table 13-2 regarding amino acid composition do not account for the apparent lower digestibility of some plant protein sources. Beans, for example, have a digestibility of 82 percent relative to milk and meat. Thus, it appears that, in addition to assessing and planning total protein intakes, it is also necessary to assess and plan for intakes of the amino acid lysine in individuals consuming proteins with low levels of lysine.

TABLE 13-2 Selected Indispensable Amino Acid Content of Protein Sources Compared with Recommended Levels

	Indispensable Amino Acid (mg/g protein)			
	Lysine	Threonine	Tryptophan	Sulfur Amino Acids
Scoring pattern, adult	47	24	6	23
FNB/IOM Recommended Protein Scoring Pattern (Child 1–3 y)	51	27	7	25
Canadian diet, 1984	61	38	12	34
U.S. diet, 1977	68	39	12	35
Wheat bread	28[a]	30	13	39
Garbanzo beans	67	37	10	26[a]
Beef	83	44	11	37
Cheddar cheese	76	33	12	29
Tofu	66	41	16	27
Brown rice	38[a]	37	13	35
Almonds	29[a]	32	15	25[a]
Peanut butter	36[a]	34	10	33
Cornmeal	28[a]	38	7	39

[a] The amino acid content in these foods is lower than the proportion recommended for the proper balance of indispensable amino acids in the total diet, based on the FNB/IOM Recommended Protein Scoring Pattern (Table 10-26). Thus a mixed diet containing a variety of protein sources is recommended.

As alluded to above, the need to plan and assess intakes of lysine is likely of greatest importance for individuals whose diets emphasize plant foods and are relatively low in total protein. For example, consider a woman who weighs 57 kg and follows a plant-based diet that provides the RDA for total protein (in her case, 57×0.8 g/kg = 45 g/day). She would be unlikely to meet her RDA for lysine (2.2 g/day) unless 50 percent or more of her dietary protein was provided from beans or tofu (rich sources of lysine). To be specific, 23 g of protein from beans and tofu would provide about 1.5 g of lysine, and 22 grams of protein from other sources, such as wheat, rice and nuts, would provide about 0.7 g of lysine. However, if her total protein intake was higher, (e.g., about 63 g/day, close to the median protein intake of women reported in the CSFII survey [Appendix Table E-16]), she could meet her RDA for lysine with much smaller amounts of beans and tofu.

INTEGRATED EXAMPLE

The preceding discussion illustrates that there are many considerations involved in dietary assessment and planning for energy and macronutrients. The example that follows illustrates how these considerations might be addressed in planning the macronutrient intake of an individual. Let us assume that the individual is a 35-year-old woman, 1.68 m in height, and weighing 69 kg. Her job is not physically active, and she does little planned exercise, so it might appear that activity level would be classified as sedentary. However, to provide a more reliable indication of her activity level, she keeps a 7-day record of her activities using a chart similar to that provided in Chapter 12 (Table 12-3), and this also confirms that she is sedentary.

Energy

Because recommended intakes of at least some nutrients relate to energy requirements, the first step would be to estimate her energy expenditure. Her BMI is 24.4, so the equation for normal-weight adults would be used. Assuming it was appropriate to maintain her current weight and activity level, the Estimated Energy Requirement for a woman with her characteristics would be about 2,000 kcal/day. Of course, her individual energy expenditure could be above or below this amount, but it provides a starting point. An additional consideration would be that her current activity level is less than the recommended of “active.” If her energy needs were estimated based on being “active,” the estimate would be 2,150 kcal, and other values listed below would change proportionally.

Fatty Acids

The AI for *n*-3 polyunsaturated fatty acid (α-linolenic acid) is 1.1 g/day, and the AI for *n*-6 polyunsaturated fatty acid (linoleic acid) is 12 g/day. Therefore, her diet should provide these levels of fatty acids, which would provide 9.9 and 108 kcal/day from *n*-3 and *n*-6 fatty acids, respectively, toward her total energy intake. Longer-chain polyunsaturated *n*-3 (approximately 10 percent) and *n*-6 fatty acids can contribute toward this AI.

Protein

The RDA for protein is 0.8 g/kg/day, so her recommended intake would be 55 g/day (69 kg × 0.8 g/kg), which would provide 220 kcal/day. In addition, she would need to meet recommended intakes of indispensable amino acids, of which lysine is most likely to be limiting. Her recommended lysine intake would be 38 mg/kg/day, or approximately 2.6 g/day.

Carbohydrate and Total Fiber

The RDA for carbohydrate for adult women is 120 g/day, which is equivalent to 480 kcal/day. More than 120 g/day will probably be needed to assure adequate energy consumption within the AMDR for carbohydrate. The AI for *Total Fiber* is 25 g/day and her diet should be planned to provide for this level of intake. The contribution of *Total Fiber* to energy (kcal/g) intake is still unclear.

Energy Distribution

The amount of energy provided by the recommended intakes of essential fatty acids, protein, and carbohydrate totals only 818 kcal/day, yet her estimated requirement is approximately 2,000 kcal/day. Her energy intake might be allocated among macronutrients as shown in Table 13-3 for an overall healthy diet.

Because the estimated energy expenditure of 2,000 kcal/day may differ from actual energy expenditure (and lead to changes in weight that may not be desirable), her weight should be monitored over time and energy intake adjusted as appropriate.

SUMMARY

The Dietary Reference Intakes (DRIs) may be used to assess nutrient intakes as well as to plan nutrient intakes. Box 13-1 summarizes the appropriate uses of the DRIs for individuals and groups.

TABLE 13-3 Example of Macronutrients in a 2,000 kcal Diet

Nutrient	AMDR[a] (%)	Range for 2,000 kcal (g)	Selected Amount (% of energy)	Amount for 2,000 kcal (g)	Energy for 2,000 kcal
Fat	20–35%	44–78	30	67 g	600 kcal
n-3 PUFA[b] (as part of total fat)	0.6–1.2%	1.3–2.7	0.8	1.8 g	16 kcal (as part of total fat)
n-6 PUFA (as part of total fat)	5–10%	11–22	7	16 g	144 kcal (as part of total fat)
Protein	10–35%	50–175	15	75 g	300 kcal
Carbohydrate	45–65%	225–325	55	275 g	1,100 kcal

[a] AMDR = Acceptable Macronutrient Distribution Range.
[b] PUFA = polyunsaturated fatty acid.

REFERENCES

Bandini LG, Vu D, Must A, Cyr H, Goldberg A, Dietz WH. 1999. Comparison of high-calorie, low-nutrient-dense food consumption among obese and non-obese adolescents. *Obes Res* 7:438–443.

Basiotis PP, Welsh SO, Cronin FJ, Kelsay JL, Mertz W. 1987. Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. *J Nutr* 117:1638–1641.

Black AE, Prentice AM, Goldberg GR, Jebb SA, Bingham SA, Livingstone MBE, Coward WA. 1993. Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. *J Am Diet Assoc* 93:572–579.

Blair SN, Kohl HW, Barlow CE. 1993. Physical activity, physical fitness, and all-cause mortality in women: Do women need to be active? *J Am Coll Nutr* 12:368–371.

Blair SN, Kohl HW, Barlow CE, Paffenbarger RS, Gibbons LW, Macera CA. 1995. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *J Am Med Assoc* 273:1093–1098.

Briefel RR, Sempos CT, McDowell MA, Chien S, Alaimo K. 1997. Dietary methods research in the Third National Health and Nutrition Examination Survey: Underreporting of energy intake. *Am J Clin Nutr* 65:1203S–1209S.

Carroll RJ, Freedman LS, Hartman AM. 1996. Use of semiquantitative food frequency questionnaires to estimate the distribution of usual intake. *Am J Epidemiol* 143:392–404.

Heitmann BL, Lissner L. 1995. Dietary underreporting by obese individuals—Is it specific or non-specific? *Br Med J* 311:986–989.

IOM (Institute of Medicine). 1994. *How Should the Recommended Dietary Allowances Be Revised?* Washington, DC: National Academy Press.

IOM. 2000. *Dietary Reference Intakes: Applications in Dietary Assessment.* Washington, DC: National Academy Press.

BOX 13-1
Uses of Dietary Reference Intakes for Healthy Individuals and Groups

Type of Use	*For the Individual*[a]	*For a Group*[b]
Assessment	**EAR**[c]**:** Use to examine the probability that usual intake is inadequate. **RDA:** Usual intake at or above this level has a low probability of inadequacy. **AI**[d]**:** Usual intake at or above this level has a low probability of inadequacy. **UL:** Intake above this level has a potential risk of adverse effects.	**EAR:** Use to estimate the prevalence of inadequate intakes within a group. **RDA:** Do not use to assess intakes of groups **AI**[d]**:** Mean usual intake at this level implies a low prevalence of inadequate intakes. **UL:** Use to estimate the percentage of the population at potential risk of adverse effects from excess nutrient intake.
Planning	**RDA**[e]**:** Aim for this intake. **AI**[d]**:** Aim for this intake. **UL:** Use as a guide to limit intake; chronic intake of higher amounts may increase the potential risk of adverse effects.	**EAR**[e]**:** Use to plan an intake distribution with a low prevalence of inadequate intakes. **AI**[d]**:** Use to plan mean intakes. **UL:** Use to plan intake distributions with a low prevalence of intakes potentially at risk of adverse effects.

[a] Requires accurate measure of usual intake. Evaluation of true status requires clinical, biochemical, and anthropometric data.
[b] Requires statistically valid approximation of distribution of usual intakes.
[c] Requires information on the variability of day-to-day intake and the variability of the requirement.
[d] For the nutrients in this report, AIs are set for infants for all nutrients, and for other age groups for *Total Fiber* and for *n*-3 and *n*-6 polyunsaturated fatty acids. The AI may be used as a guide for infants as it reflects the average intake from human milk. Infants consuming formulas with the same nutrient composition as human milk consume an adequate amount after adjustments are made for differences in bioavailability. In the context of assessing groups, when the AI for a nutrient is not based on mean intakes of a healthy population, this assessment is made with less confidence.
[e] In the case of energy, an Estimated Energy Requirement (EER) is provided; it is the dietary energy intake that is predicted (with variance) to maintain energy balance in a healthy adult of defined age, gender, weight, height, and level of physical activity, consistent with good health. In children and pregnant and lactating women, the EER is taken to include the needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health. For individuals, the EER represents the midpoint of a range within which an individual's energy requirement is likely to vary. As such, it is below the needs of half the individuals with specified characteristics and exceeds the needs of the other half. Body weight should be monitored and energy intake adjusted accordingly.

NOTE: RDA = Recommended Dietary Allowance, EAR = Estimated Average Requirement, AI = Adequate Intake, UL = Tolerable Upper Intake Level.

IOM. 2001. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* Washington, DC: National Academy Press.

Johnson RK, Goran MI, Poehlman ET. 1994. Correlates of over- and under-reporting of energy intake in healthy older men and women. *Am J Clin Nutr* 59:1286–1290.

Johnson RK, Soultanakis RP, Matthews DE. 1998. Literacy and body fatness are associated with underreporting of energy intake in US low-income women using the multiple-pass 24-hour recall: A doubly labeled water study. *J Am Diet Assoc* 98:1136–1140.

Kristal AR, Feng Z, Coates RJ, Oberman A, George V. 1997. Associations of race/ethnicity, education, and dietary intervention with the validity and reliability of a food frequency questionnaire: The Women's Health Trial Feasibility Study in Minority Populations. *Am J Epidemiol* 146:856–869.

Lichtman SW, Pisarska K, Berman ER, Pestone M, Dowling H, Offenbacher E, Weisel H, Heshka S, Matthews DE, Heymsfield SB. 1992. Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. *N Engl J Med* 327:1893–1898.

Liu K. 1994. Statistical issues related to semiquantitative food-frequency questionnaires. *Am J Clin Nutr* 59:262S–265S.

Livingstone MB, Prentice AM, Coward WA, Strain JJ, Black AE, Davies PS, Stewart CM, McKenna PG, Whitehead RG. 1992. Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. *Am J Clin Nutr* 56:29–35.

Marlett JA, Cheung TF. 1997. Database and quick methods of assessing typical dietary fiber intakes using data for 228 commonly consumed foods. *J Am Diet Assoc* 97:1139–1148.

Mertz W, Tsui JC, Judd JT, Reiser S, Hallfrisch J, Morris ER, Steele PD, Lashley E. 1991. What are people really eating? The relation between energy intake derived from estimated diet records and intake determined to maintain body weight. *Am J Clin Nutr* 54:291–295.

NRC (National Research Council). 1986. *Nutrient Adequacy. Assessment Using Food Consumption Surveys.* Washington, DC: National Academy Press.

Nusser SM, Carriquiry AL, Dodd KW, Fuller WA. 1996. A semiparametric transformation approach to estimating usual daily intake distributions. *J Am Stat Assoc* 91:1440–1449.

Prentice AM, Black AE, Coward WA, Davies HL, Goldberg GR, Murgatroyd PR, Ashford J, Sawyer M, Whitehead RG. 1986. High levels of energy expenditure in obese women. *Br Med J* 292:983–987.

Pryer JA, Vrijheid M, Nichols R, Kiggins M, Elliott P. 1997. Who are the 'low energy reporters' in the dietary and nutritional survey of British adults? *Int J Epidemiol* 26:146–154.

Schoeller DA. 1995. Limitations in the assessment of dietary energy by self-report. *Metabolism* 44:18–22.

Schoeller DA, Bandini LG, Dietz WH. 1990. Inaccuracies in self-reported intake identified by comparison with the doubly labelled water method. *Can J Physiol Pharmacol* 68:941–949.

USDA (U.S. Department of Agriculture). 2001. *USDA Nutrient Database for Standard Reference, Release 14.* Online. Nutrient Data Laboratory. Available at http://www.nal.usda.gov/fnic/foodcomp. Accessed April 2, 2002.

USDA/HHS (U.S. Department of Health and Human Services). 2000. *Nutrition and Your Health: Dietary Guidelines for Americans.* Home and Garden Bulletin No. 232. Washington, DC: U.S. Government Printing Office.